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(71) Applicant: MURATA MANUFACTURING CO., LTD.
Nagaokakyo-shi, Kyoto 617-8555 (JP)

(72) Inventors:
- ISHIHARA, Takashi,
  Murata Manufacturing Co. Ltd.
  Nagaokakyo-shi,
  Kyoto 617-8555 (JP)
- ONAKA, Kengo,
  c/o Murata Manufacturing Co. Ltd.
  Nagaokakyo-shi,
  Kyoto 617-8555 (JP)
- SATO, Jin,
  c/o Murata Manufacturing Co. Ltd.
  Nagaokakyo-shi,
  Kyoto 617-8555 (JP)
- NAGUMO, Shoji,
  c/o Murata Manufacturing Co. Ltd.
  Nagaokakyo-shi,
  Kyoto 617-8555 (JP)
- KAWAHATA, Kazunari,
  Murata Manufacturing Co. Ltd.
  Nagaokakyo-shi,
  Kyoto 617-8555 (JP)

(74) Representative: Schoppe, Fritz et al
Schoppe, Zimmermann, Stöckeler & Zinkler
Patentanwälte
Postfach 246
82043 Pullach bei München (DE)

(54) **ANTENNA STRUCTURE AND COMMUNICATION UNIT EMPLOYING IT**

(57) An antenna structure (1) includes a substrate (2) having a ground portion, a radiating electrode (3) disposed adjacent to one end of the substrate (2), and grounding extensions (4) connecting the radiating electrode (3) to the ground portion of the substrate (2). Each of the grounding extensions (4) respectively connected to opposite sides of a grounding end S of the radiating electrode (3) extends from a connection point between the grounding end (S) of the radiating electrode (3) and the grounding extension (4) towards a open end (K) of the radiating electrode (3). An end of each grounding extension (4) is connected to the ground portion of the substrate (2).

FIG 1a

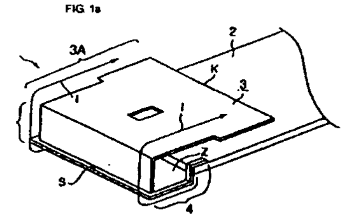


FIG 1b

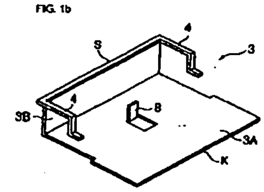
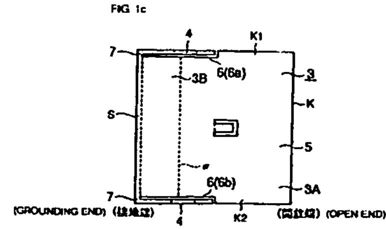


FIG 1c



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Description

Technical Field

[0001] The present invention relates to an antenna structure provided in a radio communication device, such as a mobile phone, and to a communication device equipped with such an antenna structure.

Background Art

[0002] Fig. 18a is a schematic perspective view of an example of an antenna structure (for example, see Patent Document 1). In an antenna structure 30, radiating electrodes 31, 32 are connected to each other via a connecting portion 33, and a grounding conductor 34 is disposed facing the radiating electrodes 31, 32 with a certain distance therebetween. The radiating electrodes 31, 32 are both connected to the grounding conductor 34 via a short-circuit conductor 35, which is connected to the connecting portion 33. Furthermore, the connecting portion 33 is connected to a feeding conductor 36. The feeding conductor 36 connects the radiating electrodes 31, 32 to, for example, a radio frequency circuit 37 for radio communication provided in a communication device.
Patent Document 1: Japanese Unexamined Patent Application
Publication No. 2003-101336

Disclosure of Invention

Problems to be Solved by the Invention

[0003] The antenna structure 30 may be formed by bending a conductive plate, which is given a shape shown in Fig. 18b by punching out a piece of sheet metal, at positions A, B, and C shown in Fig. 18b.

[0004] However, when the antenna structure 30 is viewed from its side in Fig. 18a, the antenna structure 30 has a U shape in which the radiating electrodes 31, 32 and the grounding conductor 34 are disposed facing each other. Forming such a U-shaped antenna structure 30 by bending a single conductive plate is extremely troublesome. Moreover, the U-shaped antenna structure 30 is also problematic in that the conductive plate requires a large surface area.

[0005] It is an object of the present invention to provide a low-cost antenna structure that can be manufactured readily, and also to provide a communication device equipped with such an antenna structure.

Means for Solving the Problems

[0006] An antenna structure according to the present invention is characterized by being provided with a substrate having a ground portion; and a radiating electrode formed of a plate material and performing an antenna operation. One end of the radiating electrode functions as a grounding end. A section of the radiating electrode proximate the other end opposite to the grounding end is disposed above the substrate with a certain distance therebetween and extends along a substrate surface of the substrate. At least opposite sides of the grounding end of the radiating electrode are respectively connected to grounding extensions extending from the grounding end towards the other end of the radiating electrode. An end of each grounding extension is connected to the ground portion of the substrate. Furthermore, a communication device according to the present invention is characterized by being provided with the antenna structure according to the present invention. Advantages

[0007] The antenna structure according to the present invention includes the radiating electrode and the grounding extensions connected respectively to at least the opposite sides of the grounding end of the radiating electrode. Each grounding extension extends from the connection point between the grounding extension and the radiating electrode towards the other end of the radiating electrode opposite to the grounding end. In addition to this configuration, when the radiating electrode and the grounding extensions are viewed from above the surface of the radiating electrode, the radiating electrode and the grounding extensions do not overlap with each other. Thus, the antenna structure can be manufactured readily as in the following manner. Specifically, a portion where the radiating electrode is to be formed and portions where the grounding extensions are to be formed are punched out in a conductive plate. Subsequently, the radiating electrode is bent upward in an erecting direction with the grounding end of the radiating electrode as being the base. This bent radiating electrode is then folded horizontally along an intermediate position of the radiating electrode. Accordingly, the radiating electrode and the grounding extensions according to the present invention can be formed readily in a continuous manner. Therefore, the present invention achieves a simplified manufacturing process of the antenna structure, thus easily achieving mass production of the antenna structure. Accordingly, the manufacturing costs required for the antenna structure can be reduced.

[0008] On the other hand, it is possible to form a grounding extension by giving it the same width as the width between the opposite side surfaces of the radiating electrode. In this case, the grounding extension faces the surface of the radiating electrode with a certain distance therebetween and extends from the grounding end of the radiating electrode towards the other end of the radiating electrode opposite to the grounding end. Moreover, an end of the grounding extension is connected to the ground portion of the substrate. In this case, in order to integrally form the radiating electrode and the above-referenced grounding extension that faces the radiating electrode with a certain distance therebetween and that has the same width as the radiating electrode, a pressing device is preferably used, which shifts a metal component (mold) in the vertical direction relatively with respect

to a conductive plate (sheet metal) so as to process the conductive plate. The conductive plate is then processed in a continuous fashion. However, such integral manufacturing of the radiating electrode and the above-referenced grounding extension using the above-referenced technique is difficult in view of the positioning of the mold, and requires high costs.

[0009] In contrast, according to the present invention, the advantages related with the simplified manufacturing process of the antenna structure, the mass production of the antenna structure, and the reduced manufacturing costs of the antenna structure can be achieved since the radiating electrode and the grounding extensions can be formed integrally by continuously processing the conductive plate. Furthermore, the present invention also has the following advantages. In detail, each of the grounding extensions conducts a current between the ground portion of the substrate and the grounding end of the radiating electrode in response to the antenna operation of the radiating electrode. Even if a grounding extension is given the same width as that of the radiating electrode and has enough width to face the radiating electrode, the current generated in response to the antenna operation of the radiating electrode concentrates in regions adjacent to the side edges of the grounding extension. In view of this aspect, even if the grounding extensions are provided only in the regions along the side edges where the current concentrates, the grounding extensions do not cause a substantial adverse effect on the electrical characteristics of the antenna structure. Accordingly, for example, the grounding extensions are preferably disposed at outer positions with respect to the respective side surfaces of the radiating electrode and are given a narrow shape such that the grounding extensions are provided only in the regions along the side edges where the current concentrates. Thus, the electrical characteristics of the antenna structure are prevented from being adversely affected, and at the same time, the surface area of the conductive plate required for forming the radiating electrode and the grounding extensions can be reduced. Accordingly, this reduces the material costs for the antenna structure, thereby contributing to cost reduction of the antenna structure.

[0010] Furthermore, the dimension of a space surrounded by the radiating electrode, the grounding extensions, and the ground portion is also known as an electrical volume of the radiating electrode. This electrical volume of the radiating electrode is responsible for the radiocommunication frequency bandwidth of the radiating electrode. The connection point between the grounding end of the radiating electrode and each grounding extension is disposed at an outer position with respect to one end of the substrate and is located below the substrate so that the end of the radiating electrode opposite to the grounding end is located above the substrate. Consequently, since the grounding end of the radiating electrode is projected below the substrate, the electrical volume of the radiating electrode is greater by the amount of the downward projected portion in comparison to a case where the grounding end of the radiating electrode is not projected below the substrate. Accordingly, this contributes to a broader frequency band.

[0011] Furthermore, in a case where the additional grounding extension is provided in a portion of the radiating electrode proximate the grounding end and between the opposite side surfaces of the radiating electrode, the connection between the radiating electrode and the ground portion of the substrate by the grounding extensions is further ensured.

[0012] Furthermore, by dividing the radiating electrode into a plurality of radiating electrode segments or by arranging a plurality of radiating electrodes in a side-by-side manner, for example, both the radiating electrode segments and the radiating electrodes may resonate with different resonant frequencies so as to further broaden the frequency bandwidth or to allow for radio communication in different frequency bands.

[0013] Furthermore, in a case where at least one of the radiating electrode segments functions as a feeding-type radiating electrode segment and the remaining radiating electrode segment functions as a non-feeding-type radiating electrode segment, the multi-resonance by the feeding-type radiating electrode segment and the non-feeding-type radiating electrode segment allows for a broader frequency band used for radio communication.

[0014] Furthermore, by providing one edge of each grounding extension with a rib for reinforcing the bending strength, the grounding extension can be prevented from deformation, such as bending and twisting. Moreover, by cutting out and bending a part of the radiating electrode to form the feeding electrode, a connecting portion between the radiating electrode and the feeding electrode can be omitted. This prevents connection failures between the radiating electrode and the feeding electrode, thereby enhancing the reliability of the antenna structure.

[0015] Furthermore, by providing at least a portion of the radiating electrode with a dielectric member, the radiating electrode can be reduced in size since the electrical length of the radiating electrode is increased as a result of a shortened wavelength effect by the dielectric member.

[0016] By providing a communication device with the antenna structure according to the present invention, the cost of the communication device can be reduced due to the cost reduction in the antenna structure. Moreover, the broader frequency band of the antenna structure contributes to a new development in communication devices, such as increased functions for communication devices.

Brief Description of the Drawings

[0017]

Fig. 1a is a schematic diagram illustrating an antenna structure according to a first embodiment.

Fig. 1b is a schematic view of a radiating electrode

and grounding extensions shown in Fig. 1a, as viewed from the bottom.

Fig. 1c is a schematic diagram illustrating one example of a conductive plate used for forming the radiating electrode and the grounding extensions shown in Fig. 1a.

Fig. 2 is a side view of the antenna structure according to the first embodiment.

Fig. 3 illustrates an example of a manufacturing process of the radiating electrode included in the antenna structure according to the first embodiment.

Fig. 4a illustrates a comparative example to the antenna structure according to the first embodiment.

Fig. 4b is a schematic diagram illustrating an example of a conductive plate used for forming a radiating electrode and a grounding extension shown in Fig. 4a.

Fig. 4c illustrates a path of a current traveling through the grounding extension included in the antenna structure shown in Fig. 4a.

Fig. 5a illustrates the simple manufacturing process of the antenna structure according to the first embodiment.

Fig. 5b illustrates the difficulty in manufacturing the antenna structure shown in Fig. 4a.

Fig. 6 illustrates a modification example of the radiating electrode included in the antenna structure according to the first embodiment.

Fig. 7 is a schematic diagram illustrating an example in which each grounding extension of the radiating electrode is provided with a reinforcement rib.

Fig. 8a is a schematic diagram illustrating another example of a conductive plate used for forming the radiating electrode and the grounding extensions shown in Fig. 8b.

Fig. 8b illustrates another example of the grounding extensions shown together with the radiating electrode.

Fig. 9 illustrates an antenna structure according to a second embodiment.

Fig. 10a illustrates another example of a radiating electrode included in the antenna structure according to the second embodiment.

Fig. 10b illustrates another example of a radiating electrode included in the antenna structure according to the second embodiment.

Fig. 11a illustrates a radiating electrode included in an antenna structure according to a third embodiment.

Fig. 11b is a schematic view of the radiating electrode and the grounding extensions shown in Fig. 11a, as viewed from the bottom.

Fig. 12 is a schematic diagram illustrating an antenna structure according to a fourth embodiment.

Fig. 13a illustrates a modification example of the antenna structure according to the fourth embodiment.

Fig. 13b is a schematic view of radiating electrodes and grounding extensions shown in Fig. 13a, as viewed from the bottom.

Fig. 14 illustrates another example of feeding means for the radiating electrode.

Fig. 15a illustrates another structural example of the radiating electrode.

Fig. 15b illustrates another structural example of the radiating electrode.

Fig. 16 is a side view illustrating an example in which the radiating electrode is provided with a dielectric member.

Fig. 17 illustrates another example of the radiating electrode.

Fig. 18a illustrates an example of an antenna structure disclosed in Patent Document 1.

Fig. 18b is a schematic view illustrating an example of a conductive plate used for forming the antenna structure shown in Fig. 18a.

Reference Numerals

[0018]

1	antenna structure
2	substrate
3	radiating electrode
4, 4'	grounding extensions
5	conductive plate
8	feeding electrode
14	rib
15, 16, 17	radiating electrode segments
18	radiating-electrode-dividing slit
22	cutout

Best Mode for Carrying Out the Invention

[0019] Embodiments of the present invention will now be described with reference to the drawings.

[0020] Fig. 1a is a schematic perspective view of an antenna structure according to a first embodiment. Fig. 2 is a schematic side view of the antenna structure according to the first embodiment. An antenna structure 1 according to the first embodiment includes a substrate 2 provided with a ground portion (not shown); a radiating electrode 3 disposed at one end of the substrate 2; and grounding extensions 4 that connect the radiating electrode 3 with the ground portion of the substrate 2. The substrate 2 is a circuit substrate contained in a radio communication device, such as a mobile phone.

[0021] The radiating electrode 3 includes a main-surface portion 3A and an erected portion 3B. The erected portion 3B has an end S that defines a grounding end. On the other hand, the main-surface portion 3A has an end K that defines an open end (i.e. the end opposite to the grounding end). The grounding extensions 4 are respectively connected to opposite sides of the grounding end of the radiating electrode 3, and extend outward of the radiating electrode 3 from the grounding end of the radiating electrode 3 toward the open end of the radiating

electrode 3.

[0022] As shown in Fig. 1c, the radiating electrode 3 and the grounding extensions 4 are formed by pressing and bending a rectangular conductive plate 5. In detail, by bending the conductive plate 5 along a dotted line α shown in Fig. 1c, the conductive plate 5 is sectioned into the main-surface portion 3A and the erected portion 3B. The main-surface portion 3A is set in an opposed manner to the substrate surface of the substrate 2 at one end thereof while being separated from the substrate surface by a certain distance. On the other hand, the erected portion 3B stands vertically at an outer position with respect to the end of the substrate 2 provided with the radiating electrode 3.

[0023] Opposite side edges K1, K2 of the conductive plate 5 are respectively provided with slits 6 (6a, 6b), which are formed by pressing (punching). The slits 6 extend into the conductive plate 5 from the respective sides thereof and then toward the grounding end of the radiating electrode 3. In the first embodiment, the grounding extensions 4 are formed as a result of the formation of the slits 6 (6a, 6b), meaning that the grounding extensions 4 are respectively formed by cutting side portions of the conductive plate 5 along the opposite side edges K1, K2 so that these side portions are split from the radiating electrode 3. Each grounding extension 4 is bent so as to extend toward the substrate 2 from the base point thereof, that is, a connection point 7 between the grounding extension 4 and the radiating electrode 3.

[0024] In the first embodiment, the grounding end of the radiating electrode 3 is located below the substrate 2. In other words, the connection point between the radiating electrode 3 and each grounding extension 4 is located below the substrate 2. Each grounding extension 4 has a first segment that extends toward the substrate 2 from the connection point between the radiating electrode 3 and the grounding extension 4 in a direction perpendicular to the erected portion 3B of the radiating electrode 3; a second segment that is erected along the surface of the end of the substrate 2 provided with the radiating electrode 3; and a third segment which is formed by bending an end portion of the second erected segment along the top surface of the substrate 2 and which is connected to the ground portion of the substrate 2.

[0025] The grounding extensions 4 and the substrate 2 may be joined together using a jointing material, such as solder, or may be joined together using caulking members. On the other hand, Fig. 2 illustrates an example in which the antenna structure 1 is entirely housed within an end portion of a housing (cover) 10 of a communication device, as shown with a chain line. According to the example shown in this drawing, the main-surface portion 3A of the radiating electrode 3 receives a downward pressing force from the cover 10. Due to this downward pressing force from the cover 10, the entire radiating electrode 3 is pressed downward such that the grounding extensions 4 are connected to the top surface of the substrate 2 by being in pressure-contact with the top surface. Accordingly, the grounding extensions 4 may be connected with the substrate 2 in such a pressure-contact fashion. As described above, there are various techniques for connecting the grounding extensions 4 and the substrate 2, and therefore, the connection technique is not limited to those mentioned above.

[0026] Fig. 1b is a schematic view of the radiating electrode 3 and the grounding extensions 4 shown in Fig. 1a, as viewed from the bottom. Referring to Figs. 1a and 1b, according to the first embodiment, a part of the main-surface portion 3A of the radiating electrode 3 is bent towards the substrate 2, such that this bent part defines a feeding electrode 8. A section of the substrate surface proximate the end of the substrate 2 provided with the radiating electrode 3 has a feeding pad (not shown) disposed thereon, which is connected to a radio frequency circuit 11 (see Fig. 2) of a communication device. The radio frequency circuit 11 is used for radio communication. The feeding electrode 8 is connected to the feeding pad. The radiating electrode 3 is connected to the radio frequency circuit 11 via the feeding electrode 8 and the feeding pad. The feeding electrode 8 and the feeding pad may be connected to each other by soldering or by being in pressure-contact with each other using the pressing force applied to the radiating electrode 3 from the cover 10. Consequently, the connection technique between the two components is not limited.

[0027] For example, when a sending signal is supplied to the radiating electrode 3 from the radio frequency circuit 11 via the feeding electrode 8, for example, a current I is conducted in a loop-like manner through the radiating electrode 3 in response to this signal supply by traveling through the grounding extensions 4 and the erected portion 3B of the radiating electrode 3 towards the main-surface portion 3A, as shown in Fig. 1a. The radiating electrode 3 is thus excited, whereby the sending signal is radio-transmitted. On the other hand, when a signal is received by the radiating electrode 3 from an external source, the radiating electrode 3 is excited in response to the signal reception. The received signal is then transmitted to the radio frequency circuit 11 from the radiating electrode 3 via the feeding electrode 8.

[0028] The antenna structure 1 according to the first embodiment has the configuration described above. An example of a manufacturing process of the radiating electrode 3 and the grounding extensions 4 included in the antenna structure 1 according to the first embodiment will now be described with reference to Fig. 3. As shown in section M1 of sheet metal 12, an outer periphery of a region where the radiating electrode 3 and the grounding extensions 4 are to be formed is punched out by pressing. Subsequently, as shown in section M2, the slits 6 are respectively formed along the opposite side edges K1, K2 of the punched-out region by pressing, thereby splitting the portions that are to become the grounding extensions 4 from the portion that is to become the radiating electrode 3.

[0029] Then, as shown in section M3, an outer periph-

ery of the feeding electrode 8 is punched out by pressing. As shown in section M4, the feeding electrode 8 is bent downward. As shown in section M5, the grounding extensions 4 are bent into shape using a mold. Subsequently, the radiating electrode 3 is bent upward in the erecting direction with the grounding end of the radiating electrode 3 as being the base. Then, as shown in section M6, this bent radiating electrode 3 is folded horizontally along an intermediate position of the radiating electrode 3. Thus, the main-surface portion 3A and the erected portion 3B of the radiating electrode 3 are formed. Accordingly, the radiating electrode 3, the grounding extensions 4, and the feeding electrode 8 are formed.

[0030] According to the first embodiment, when the radiating electrode 3 and the grounding extensions 4 are viewed from above the drawing of Fig. 1a, for example, the radiating electrode 3, the grounding extensions 4, and the feeding electrode 8 do not overlap with each other. For this reason, the radiating electrode 3 can be formed by pressing and bending the sheet metal 12 in a continuous fashion. Consequently, the manufacturing process of the antenna structure 1 is simplified, thus easily achieving mass production of the antenna structure 1. Moreover, since the mold used for the bending has a simple shape, the time required for designing the mold can be shortened.

[0031] Furthermore, because the radiating electrode 3, the grounding extensions 4, and the feeding electrode 8 are formed by processing a single conductive plate in the first embodiment, the manufacturing process does not require a connection step for connecting the radiating electrode 3 to the grounding extensions 4 and a connection step for connecting the radiating electrode 3 to the feeding electrode 8. Moreover, since the antenna structure 1 according to the first embodiment is formed simply by connecting the ends of the grounding extensions 4 to the substrate 2 and connecting the end of the feeding electrode 8 to the substrate 2, the assembly process of the antenna structure 1 is simplified.

[0032] Furthermore, because the radiating electrode 3 and the grounding extensions 4 as well as the radiating electrode 3 and the feeding electrode 8 are not joined using a jointing material, such as solder, the problems related with connection failures between the radiating electrode 3 and the grounding extensions 4 and between the radiating electrode 3 and the feeding electrode 8 are solved. Moreover, the antenna characteristics are prevented from, for example, varying, which may be caused by variations in the connection state between the radiating electrode 3 and the grounding extensions 4 or the connection state between the radiating electrode 3 and the feeding electrode 8. Accordingly, this enhances the reliability of the antenna structure 1 and the communication device equipped with the antenna structure 1.

[0033] On the other hand, it is possible to form a radiating electrode 20 and a grounding extension 21 shown in Fig. 4a in a perspective view by bending a conductive plate along dotted lines shown in Fig. 4b. Although the radiating electrode 20 is similar to the radiating electrode 3 according to the first embodiment in that the radiating electrode 20 includes a main-surface portion 20A and an erected portion 20B, the grounding extension 21 is different from the grounding extensions 4 according to the first embodiment. Specifically, the grounding extensions 4 according to the first embodiment are formed by splitting the side portions of the conductive plate 5 from the radiating electrode 3 with the slits 6. In contrast, according to the configuration shown in Fig. 4b, the grounding extension 21 is simply an extended section of the radiating electrode 20 and extends from one end of the conductive plate in a direction in which the main-surface portion 20A and the erected portion 20B are arranged. For this reason, according to the configuration shown in Figs. 4a and 4b, since the conductive plate requires this extended section (that is, a section of the conductive plate where the grounding extension 21 is formed), the conductive plate requires a larger surface area for forming the radiating electrode and the grounding extension in comparison to the antenna structure 1 according to the first embodiment.

[0034] On the other hand, when the radiating electrode 20 is viewed from a side, the side view thereof is the same as the side view of the radiating electrode 3 (see Fig. 2). For this reason, if the radiating electrodes 3 and 20 have the same size, the two electrodes have substantially the same electrical volume. In other words, if the main-surface portions 3A and 20A have the same size and the erected portions 3B and 20B have the same size, and if the distance between the erected portion 3B and the substrate 2 is the same as the distance between the erected portion 20B and the substrate 2, and moreover, if the erected portions 3B and 20B are projected downward by the same length, the radiating electrodes 3 and 20 have substantially the same electrical volume.

[0035] Furthermore, each of the grounding extensions 4 according to the first embodiment is smaller in width in comparison to the grounding extension 21. This might appear that the current traveling from the ground portion of the substrate 2 towards the radiating electrode 3 through the grounding extensions 4 could possibly be adversely affected. However, even if the grounding extension 21 is larger in width, the current traveling from the substrate 2 towards the radiating electrode 20 concentrates in regions adjacent to the side edges of the grounding extension 21, as shown in Fig. 4c. Consequently, even if the narrow frame-like grounding extensions 4 are disposed respectively on the opposite sides of the radiating electrode 3 as in the first embodiment, the current traveling from the substrate 2 to the radiating electrode 3 through the grounding extensions 4 is prevented from being adversely affected. In other words, there is no need to concern that the antenna characteristics might be deteriorated due to the narrower grounding extensions 4.

[0036] Accordingly, in comparison to the configuration shown in Fig. 4a, the antenna structure 1 according to

the first embodiment can be manufactured simply while preventing deterioration of the electrical characteristics of the radiating electrode (antenna) caused by, for example, a reduced electrical volume of the radiating electrode. Moreover, the first embodiment is also advantageous in that the surface area of the conductive plate required for forming the radiating electrode can be reduced significantly.

[0037] Furthermore, the radiating electrode 20 and the grounding extension 21 shown in Fig. 4a are supposedly formed by using, for example, a pressing device that shifts a metal component in the vertical direction relatively with respect to the conductive plate for bending the conductive plate. In this case, for example, after the radiating electrode 20 is bent in the erecting direction with respect to the grounding extension 21 as shown with a solid line in Fig. 5b, a metal component 26 shown in Fig. 5b with a dotted line is desirably shifted vertically in the drawing to the position indicated by the dotted line in Fig. 5b in order to bend the main-surface portion 20A of the radiating electrode 20 in the horizontal direction (a direction parallel to the grounding extension 21) using the metal component 26. However, in the configuration shown in Fig. 4a, the metal component 26 cannot be set in that position indicated by the dotted line in the drawing due to the presence of the grounding extension 21. For this reason, it is difficult to form the structure shown in Fig. 4a by using the pressing device that shifts the metal component in the vertical direction relatively with respect to the conductive plate for bending the conductive plate.

[0038] In contrast, with the antenna structure 1 according to the first embodiment, after the radiating electrode 3 is bent upward as shown with a solid line in Fig. 5a, the metal component 26 can be positioned along this bent radiating electrode 3 without being interfered by the grounding extensions 4. Thus, the main-surface portion 3A of the radiating electrode 3 can be bent horizontally using the metal component 26. In other words, according to the configuration of the first embodiment, the antenna structure 1 can be manufactured easily using a pressing device that shifts the metal component in the vertical direction relatively with respect to the conductive plate for bending the conductive plate.

[0039] As described above with reference to Fig. 1, the opposite side portions of the radiating electrode 3 (the conductive plate 5) respectively form the grounding extensions 4. On the other hand, Fig. 6 illustrates a modification example in which an additional grounding extension 4' is provided in addition to the grounding extensions 4 disposed on the opposite sides of the conductive plate 5. Specifically, the additional grounding extension 4' is disposed at the grounding end and between the opposite sides of the conductive plate 5, and is split from the radiating electrode 3 by a grounding-extension-formation slit. Such an additional grounding extension 4' contributes to better reliability of the connection between the grounding extensions 4 and the substrate 2. In Fig. 6, the radiating electrode 3 and the grounding extensions 4, 4' are illustrated as viewed from the side proximate the substrate 2 (from the bottom). Moreover, there is a case where a component of a communication device, such as a speaker, is disposed in a space Z (see Fig. 1a) adjacent to the exterior of the end of the substrate 2 provided with the radiating electrode 3, that is, a space Z surrounded by the radiating electrode 3 and the grounding extensions 4. In a case where the additional grounding extension 4' is provided, the position and the width of the additional grounding extension 4' are set in view of, for example, the positioning of the component disposed in the space Z.

[0040] In the first embodiment, the grounding extensions 4 are much narrower than the radiating electrode 3. For this reason, the grounding extensions 4 may possibly be subject to deformation, such as bending or twisting. In order to prevent this, a bending-strength reinforcement rib 14 may be provided along an edge of each grounding extension 4, as shown in Fig. 7. Each bending-strength reinforcement rib 14 may be formed by folding a protruding portion provided on the edge of the corresponding grounding extension 4.

[0041] Furthermore, in Fig. 1, the grounding-extension-formation slits 6 provided in the conductive plate 5 extend into the conductive plate 5 from the respective sides thereof and then toward the grounding end of the radiating electrode 3. Alternatively, for example, as shown in Fig. 8a, each of the slits 6 may extend linearly along the corresponding side surface of the conductive plate 5 from the open end of the radiating electrode 3 towards the grounding end. Due to these slits 6, the grounding extensions 4 are split from the radiating electrode 3, thereby forming the antenna structure 1 shown in Fig. 8b in a perspective view.

[0042] The orientation of the antenna structure 1 is not limited to the orientation shown in Fig. 1. For example, the substrate 2 may be disposed in an erected fashion or the main-surface portion 3A may be disposed facing the bottom surface of the substrate 2.

[0043] A second embodiment will now be described. In the description of the second embodiment below, the components that are the same as those in the first embodiment are given the same reference numerals, and the description of those components will be omitted.

[0044] In the second embodiment shown in Fig. 9 in a perspective view, the radiating electrode 3 (conductive plate 5) has two radiating-electrode-dividing slits 18 (18a, 18b) with a certain distance therebetween. The radiating-electrode-dividing slit 18a extend along one of the sides of the radiating electrode 3 from the open end of the radiating electrode 3 (conductive plate 5) to the grounding end of the radiating electrode 3. On the other hand, the radiating-electrode-dividing slit 18b extends into the radiating electrode 3 from the other side thereof and then toward the grounding end of the radiating electrode 3 along the side of the radiating electrode 3.

[0045] The radiating-electrode-dividing slits 18a, 18b divide the radiating electrode 3 into a plurality of radiating

electrode segments 15, 16, 17. The radiating electrode segments 15, 16, 17 respectively have main-surface subsegments (15A, 16A, 17A) and erected subsegments (15B, 16B, 17B). The radiating electrode segments 15, 16, 17 are mutually connected to the two grounding extensions 4 of the radiating electrode 3 at the base end (the grounding end) of the erected portion 3B (15B, 16B, 17B) so as to be grounded to the ground portion of the substrate 2.

[0046] In the second embodiment, one radiating electrode segment 15 is provided with the feeding electrode 8 formed by cutting out and bending a part of the main-surface subsegment 15A. The radiating electrode segment 15 thus functions as a feeding-type radiating electrode segment. On the other hand, the remaining radiating electrode segments 16, 17 function as non-feeding-type radiating electrode segments. Each of the non-feeding-type radiating electrode segments 16, 17 is electromagnetically coupled to the feeding-type radiating electrode segment 15 and thus performs an antenna operation together with the radiating electrode segment 15 to produce a multi-resonant state.

[0047] According to the second embodiment, the multi-resonance by the plurality of radiating electrode segments 15, 16, 17 allows for a broader frequency band used for radio communication by the antenna structure 1, or allows for radio communication in different frequency bands.

[0048] In the second embodiment, the radiating electrode 3 is provided with the two radiating-electrode-dividing slits 18. Alternatively, in view of, for example, the required frequency bandwidth based on, for example, the dimension or the specification of the radiating electrode 3, the radiating electrode 3 may be provided with only one radiating-electrode-dividing slit 18 or three or more radiating-electrode-dividing slits 18. In the former case, the radiating electrode 3 is divided into two radiating electrode segments, whereas in the latter case, the radiating electrode 3 is divided into four or more radiating electrode segments.

[0049] Furthermore, in the second embodiment, the grounding extensions 4 are disposed on the opposite sides of the radiating electrode 3 (conductive plate 5). Alternatively, as described in the first embodiment, an additional grounding extension 4' as shown in Fig. 6 may be provided in addition to the grounding extensions 4 disposed on the opposite sides of the radiating electrode 3.

[0050] Furthermore, in the second embodiment shown in Fig. 9, only one of the plurality of radiating electrode segments 15, 16, 17 functions as a feeding-type radiating electrode segment. Alternatively, in view of, for example, the specification, at least two of the plurality of radiating electrode segments may each be provided with the feeding electrode 8 as shown in Fig. 10a, such that a plurality of feeding-type radiating electrode segments are provided. As a further alternative, without providing any non-feeding-type radiating electrode segments, all of the radiating electrode segments may be a feeding type.

[0051] Furthermore, as shown in Fig. 10b, the end of each radiating-electrode-dividing slit 18 proximate the grounding end may be disposed at a position higher than the position shown in Fig. 9. In detail, for example, a dimension H from the base point of the erected portion 3B to the end of each radiating-electrode-dividing slit 18, as shown in Fig. 10b, is set at 0.5 mm or more. Accordingly, this increases the strength of the radiating electrode 3.

[0052] A third embodiment will now be described. In the description of the third embodiment below, the components that are the same as those in the first and second embodiments are given the same reference numerals, and the description of those components will be omitted.

[0053] Figs. 11a and 11b are schematic perspective views of the radiating electrode included in the antenna structure according to the third embodiment. Fig. 11a illustrates the radiating electrode 3 as viewed from above the substrate 2. Fig. 11b illustrates the radiating electrode 3 as viewed from below the substrate 2.

[0054] In the third embodiment, the grounding extensions 4 are respectively provided at the opposite sides of the grounding end of the radiating electrode 3, and moreover, the additional grounding extension 4' is provided at the grounding end and between the opposite sides of the radiating electrode 3. Furthermore, the radiating electrode 3 is provided with a cutout 22 extending from a cutout gap Q corresponding to the additional grounding extension 4' to the open end of the main-surface portion 3A. The cutout gap Q and the cutout 22 together define a radiating-electrode-dividing slit, such that the radiating electrode 3 is divided into the plurality of radiating electrode segments 15, 16.

[0055] In the third embodiment shown in Figs. 11a and 11b, one of the radiating electrode segments 15, 16 is provided with the feeding electrode 8 so as to function as the feeding type, whereas the other radiating electrode segment functions as the non-feeding type. The feeding-type and the non-feeding-type radiating electrode segments 15, 16 produce a multi-resonant state. This multi-resonance allows for a broader frequency band, or allows for radio communication in different frequency bands.

[0056] Although one of the radiating electrode segments 15, 16 functions as the feeding type while the other radiating electrode segment functions as the non-feeding type in the third embodiment shown in Figs. 11a and 11b, both radiating electrode segments 15, 16 may alternatively function as the feeding type.

[0057] Furthermore, in the third embodiment shown in Figs. 11a and 11b, although only one additional grounding extension 4' is provided, which is formed by cutting out and bending a part of the radiating electrode 3, the radiating electrode 3 may alternatively be provided with a plurality of additional grounding extensions 4'. In that case, a plurality of cutouts 22 that continue from the respective cutout gaps Q corresponding to the additional grounding extensions 4' is provided. The cutout gaps Q

and the cutouts 22 form radiating-electrode-dividing slits, which divide the radiating electrode 3 into three or more radiating electrode segments. In that case, for example, the radiating electrode segments may resonate with different resonant frequencies so as to further broaden the frequency bandwidth, or to allow for radio communication in different frequency bands.

[0058] A fourth embodiment will now be described. In the description of the fourth embodiment below, the components that are the same as those in the first to third embodiments are given the same reference numerals, and the description of those components will be omitted.

[0059] In the antenna structure according to the fourth embodiment shown in Fig. 12, one end of the substrate 2 is provided with a plurality of radiating electrodes 3 (3α, 3β) which are separated from each other by a certain distance. At least one of the radiating electrodes 3 (3α, 3β) has the configuration of the radiating electrode 3 according to any one of the first to third embodiments.

[0060] In the fourth embodiment shown in Fig. 12, the radiating electrode 3 (3α), which corresponds to the type according to the second embodiment having the plurality of radiating electrode segments 15, 16, and the radiating electrode 3 (3β), which is a modification type of the radiating electrode 3 according to the first embodiment, are arranged in a side-by-side manner. Instead of having the grounding extensions 4 connected to the opposite sides of the grounding end of the radiating electrode 3β, the radiating electrode 3β of the modification type only has one grounding extension 4 (4β) connected to one side of the grounding end of the radiating electrode 3β. In this case, the radiating electrode 3β is a non-feeding-type that is not provided with the feeding electrode 8, and is electromagnetically coupled to the radiating electrode segment 15 of the radiating electrode 3α of the feeding type so as to produce a multi-resonant state.

[0061] As an alternative to the configuration shown in Fig. 12, a configuration shown in Fig. 13a, for example, may also be applied. Specifically, in the example shown in Fig. 13a, a plurality of radiating electrodes 3 (3α, 3β) is arranged in a side-by-side manner such that each radiating electrode 3 corresponds to the type according to the first embodiment. In this case, one of the radiating electrodes 3α, 3β functions as the feeding type while the other functions as the non-feeding type. Fig. 13b illustrates the radiating electrodes 3α, 3β shown in Fig. 13a as viewed from the side proximate the substrate 2 (from the bottom). In the example shown in Figs. 13a and 13b, although one of the radiating electrodes 3α, 3β functions as the feeding type while the other functions as the non-feeding type, alternatively, both radiating electrodes 3α, 3β may function as the feeding type.

[0062] In the fourth embodiment, as shown in Figs. 13a and 13b, the plurality of radiating electrodes 3 of the same type according to any one of the first to third embodiments may be arranged in a side-by-side manner with a certain distance therebetween, or a combination of the radiating electrodes of different types according to the first to third embodiments may be arranged in a side-by-side manner, or at least one of the radiating electrodes according to the first to third embodiments and a radiating electrode having a configuration different to the configurations according to the first to third embodiments may be arranged in a side-by-side manner with a certain distance therebetween.

[0063] In a case where a combination of the radiating electrodes of the same type or different types according to the first to third embodiments is to be arranged in a side-by-side manner, the radiating electrodes can be formed simultaneously in their arranged state by pressing and bending the sheet metal 12, as described previously.

[0064] A fifth embodiment will now be described. The fifth embodiment relates to a communication device. The communication device according to the fifth embodiment is equipped with the antenna structure 1 according to any one of the first to fourth embodiments. Since the antenna structure 1 has already been described above in detail, such a description will be omitted below. Moreover, other than the configuration of the antenna structure 1, the communication device may have various types of configurations, and therefore, any type of configuration may be applied to the communication device. The description of such a configuration will therefore be omitted below.

[0065] The technical scope of the present invention is not limited to the first to fifth embodiments, and modifications are permissible within the scope and spirit of the present invention. For example, in each of the first to fifth embodiments, although the feeding-type radiating electrode 3 (or the radiating electrode segment 15) is provided with the feeding electrode 8 formed by cutting out and bending a part of the main-surface portion 3A (15A), the means for connecting the feeding-type radiating electrode 3 (the radiating electrode segment 15) to the radio frequency circuit 11 of the communication device is not limited to the feeding electrode 8. For example, a feeding pin 23 formed of a conductive material shown in Fig. 14 in a side view may alternatively be applied. The feeding pin 23 has elasticity and is connected to a radio-frequency-circuit-connection feeding pad (not shown) disposed on the substrate surface of the substrate 2.

[0066] Furthermore, although the feeding electrode 8 is formed by cutting out and bending a part of the main-surface portion 3A of the radiating electrode 3, the position of the feeding electrode 8 is not limited. For example, the feeding electrode 8 may be formed alternatively by cutting out and bending a part of the erected portion 3B. Furthermore, the connection point between the feeding pin 23 and the radiating electrode 3 is not limited to the point in the example shown in Fig. 14. The feeding position in the radiating electrode 3 is set in view of, for example, impedance matching between the radiating electrode 3 and the radio frequency circuit 11, and therefore, the feeding position in the radiating electrode 3 is not limited to the position shown in, for example, Fig. 14.

[0067] Furthermore, although the end of each grounding extension 4 is connected to the substrate 2 in the first

to fifth embodiments, the end of each grounding extension 4 may alternatively be connected to a housing that can function as a ground, or to, for example, a ground portion provided in a housing composed of an insulating material instead of connecting the end of each grounding extension 4 to the substrate 2. This applies to a case where the antenna structure 1 according to each of the first to fifth embodiments is housed inside a housing of the communication device, such that the housing itself is composed of a conductive material, such as a magnesium alloy, and can thus function as a ground, or that the housing composed of an insulating material, such as resin, is provided with a conducting portion (i.e. the ground portion) that functions as a ground.

[0068] Furthermore, although the first to fifth embodiments each apply a direct-feeding technique for directly connecting the radiating electrode 3 to the radio frequency circuit 11 via the feeding electrode 8, a capacitive-feeding technique may alternatively be applied in which the radiating electrode 3 is connected to the radio frequency circuit 11 via capacitance.

[0069] Furthermore, in a case where the antenna structure 1 is, for example, housed in an end portion of the cover 10 of the communication device, the radiating electrode 3 may have a shape that extends along the inner surface of the end portion of the cover 10, as shown in examples of Figs. 15a and 15b, in order to increase the electrical volume of the radiating electrode 3 to the utmost extent. Specifically, in the example shown in Fig. 15a, the erected portion 3B is located below the substrate 2 with respect to the main-surface portion 3A, and the main-surface portion 3A has a partly tapered surface that corresponds to the shape of the cover 10. On the other hand, in the example shown in Fig. 15b, the connecting section between the main-surface portion 3A and the erected portion 3B is not perpendicular but is given a round shape that corresponds to the shape of the cover 10.

[0070] Furthermore, in order to reduce the size of the radiating electrode 3, for example, a surface of the radiating electrode 3 proximate the substrate 2 may partly or entirely be provided with a dielectric member 24, as shown in Fig. 16 in a side view. Based on a shortened wavelength effect by the dielectric member 24, the radiating electrode 3 can be reduced in size.

[0071] Furthermore, for example, the dielectric member 24 may be disposed between the radiating electrode segments of the radiating electrode 3 or between the plurality of radiating electrodes arranged in a side-by-side manner. As a further alternative, the end of the radiating electrode 3 opposite to the grounding end thereof may be bent towards the substrate 2, as shown in Fig. 17 in a side view. Industrial Applicability

[0072] Accordingly, the present invention achieves a small-size, low-cost, high-performance antenna structure and a communication device equipped with such an antenna structure. Therefore, the present invention can be advantageously applied to, for example, common, small-size radio communication devices and to antenna structures incorporated in such devices.

Claims

1. An antenna structure comprising a substrate having a ground portion; and a radiating electrode formed of a plate material and performing an antenna operation, wherein one end of the radiating electrode functions as a grounding end, wherein a section of the radiating electrode proximate the other end opposite to the grounding end is disposed above the substrate with a certain distance therebetween and extends along a substrate surface of the substrate, wherein at least opposite sides of the grounding end of the radiating electrode are respectively connected to grounding extensions extending from the grounding end towards the other end of the radiating electrode, and wherein an end of each grounding extension is connected to the ground portion of the substrate.

2. The antenna structure according to Claim 1, wherein the radiating electrode and the grounding extensions are housed inside a housing functioning as a ground or inside a housing having a ground portion, and wherein the end of each grounding extension is connected to the housing functioning as a ground or to the ground portion provided in the housing instead of being connected to the ground portion of the substrate.

3. The antenna structure according to Claim 1, wherein a portion of the radiating electrode proximate the grounding end and between opposite side surfaces of the radiating electrode is cut out so as to form a grounding-extension-formation slit in the radiating electrode, said cutout portion defining an additional grounding extension.

4. The antenna structure according to Claim 1, wherein the grounding end of the radiating electrode is disposed at an outer position with respect to one end of the substrate, wherein the connection point between the grounding end of the radiating electrode and each grounding extension is located below the substrate, and wherein the section of the radiating electrode proximate the other end opposite to the grounding end is located above the substrate.

5. The antenna structure according to Claim 1, wherein the radiating electrode is provided with at least one radiating-electrode-dividing slit extending towards the grounding end, such that the radiating electrode is divided into a plurality of radiating electrode segments.

6. The antenna structure according to Claim 5, wherein at least one of the radiating electrode segments functions as a feeding-type radiating electrode segment and the remaining radiating electrode segment functions as a non-feeding-type radiating electrode segment, the non-feeding-type radiating electrode segment being electro-magnetically coupled to the feeding-type radiating electrode segment, thereby performing the antenna operation producing a multi-resonant state together with the feeding-type radiating electrode segment.

7. An antenna structure comprising a plurality of radiating electrodes arranged with a certain distance therebetween at one end of a substrate, wherein at least one of the radiating electrodes comprises the radiating electrode set forth in Claim 1.

8. An antenna structure comprising a plurality of radiating electrodes arranged with a certain distance therebetween at one end of a substrate, wherein at least one of the radiating electrodes comprises the radiating electrode set forth in Claim 5.

9. An antenna structure comprising a plurality of radiating electrodes arranged with a certain distance therebetween at one end of a substrate, wherein at least one of the radiating electrodes comprises the radiating electrode set forth in Claim 6.

10. The antenna structure according to Claim 1, wherein a part of the radiating electrode is cut out and bent towards the substrate, said part functioning as a feeding electrode for connecting the radiating electrode to a feeding pad provided on the substrate, the feeding pad being connected to a radio frequency circuit.

11. The antenna structure according to Claim 1, wherein the substrate surface is provided with a feeding pad connected to a radio frequency circuit, the feeding pad and the radiating electrode positioned thereabove are connected to each other with a conductor having elasticity.

12. The antenna structure according to Claim 1, wherein at least a portion of the radiating electrode is provided with a dielectric member.

13. The antenna structure according to Claim 1, wherein an edge of each grounding extension is provided with a rib for reinforcing the bending strength.

14. A communication device comprising the antenna structure according to Claim 1.

FIG. 1a

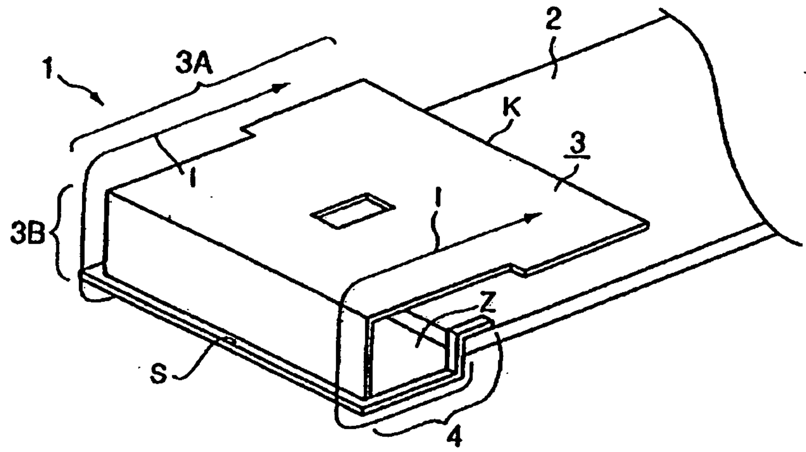


FIG. 1b

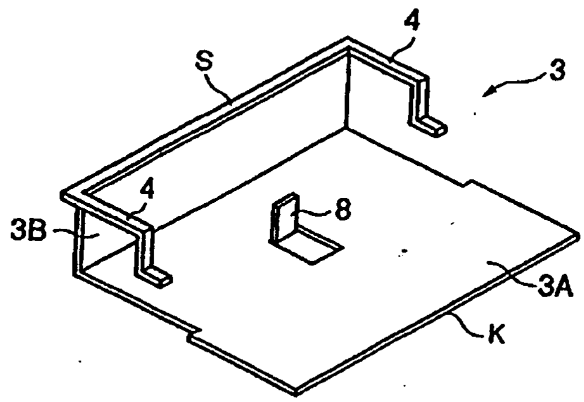


FIG. 1c

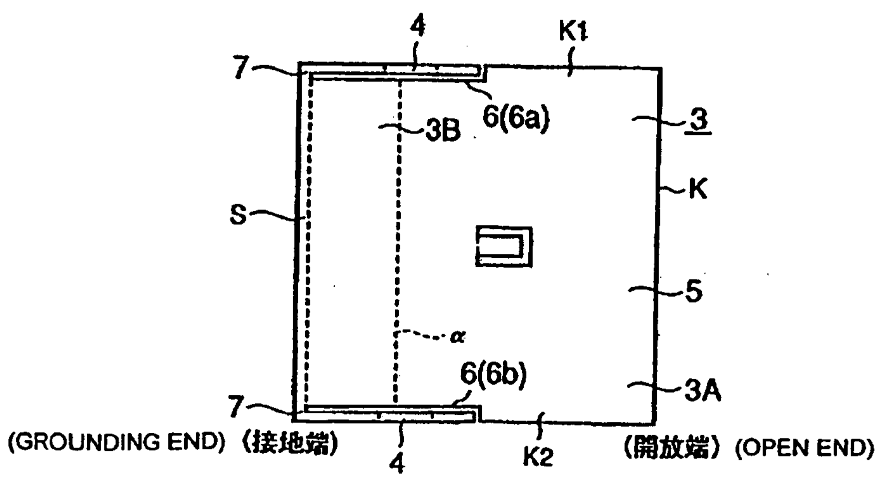


FIG. 2

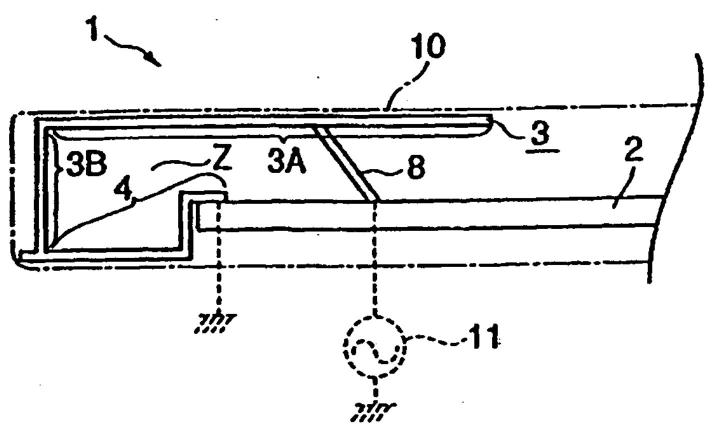


FIG. 3

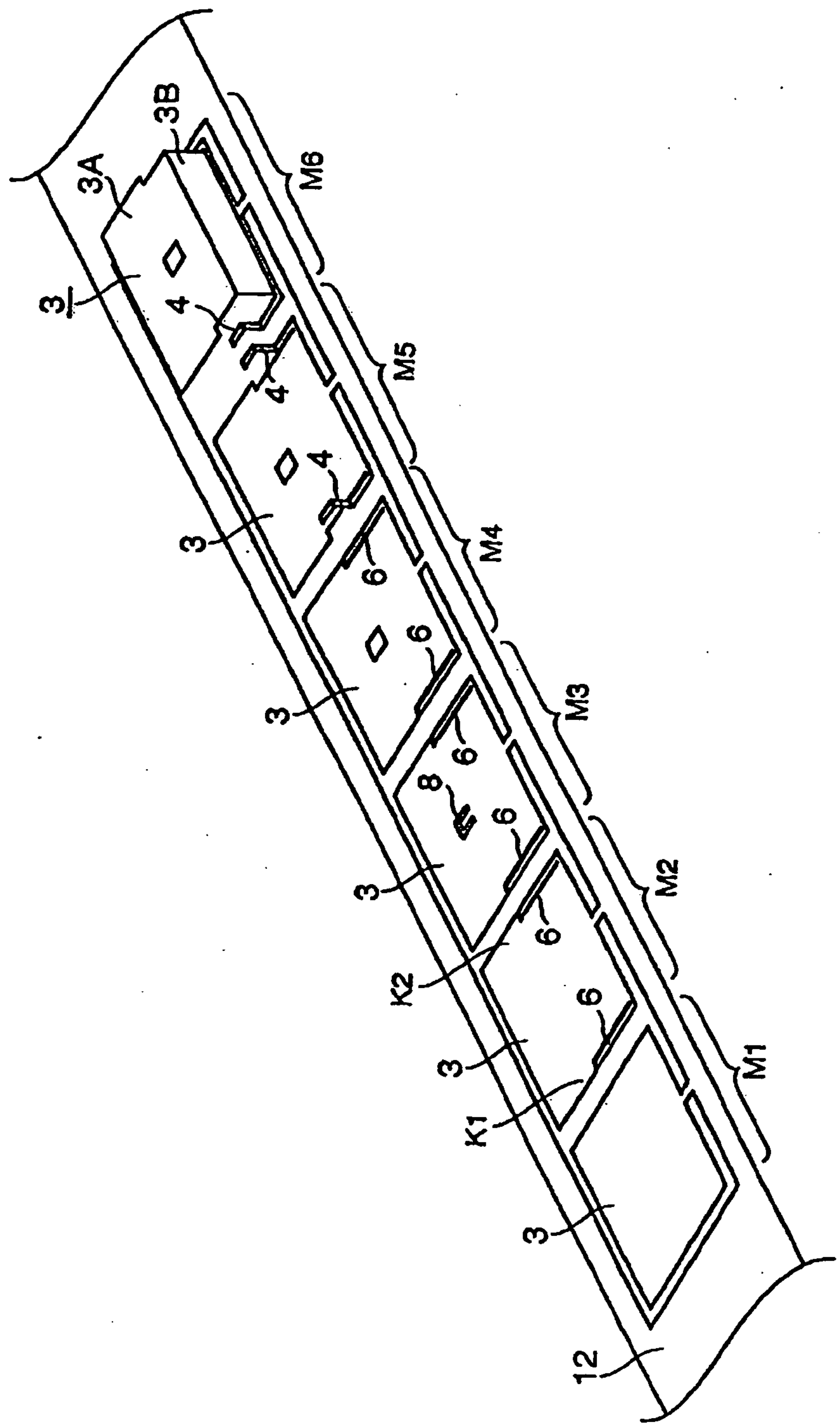


FIG. 4a

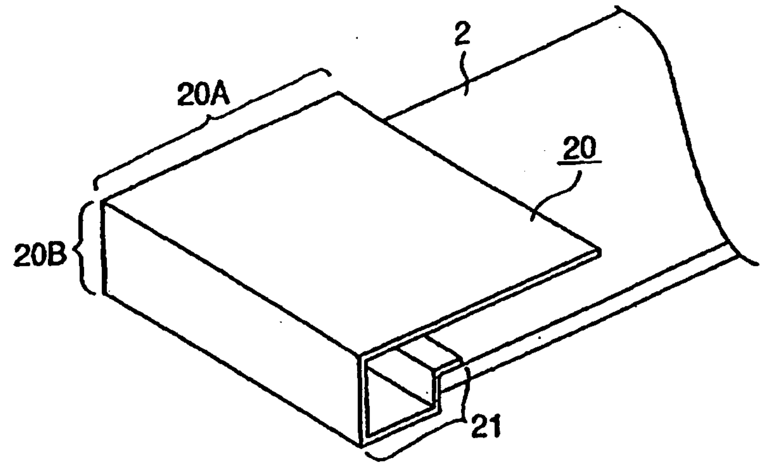


FIG. 4b

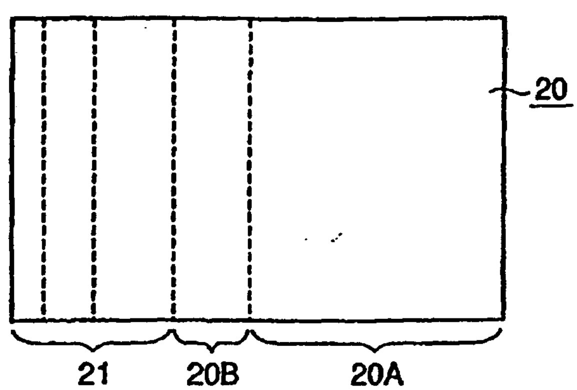


FIG. 4c

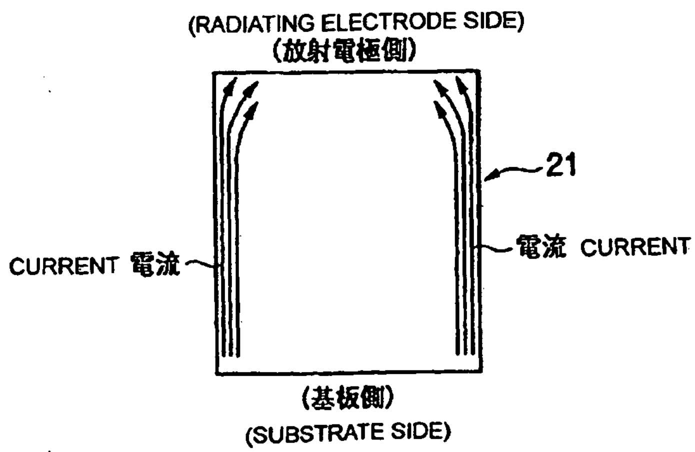


FIG. 5a

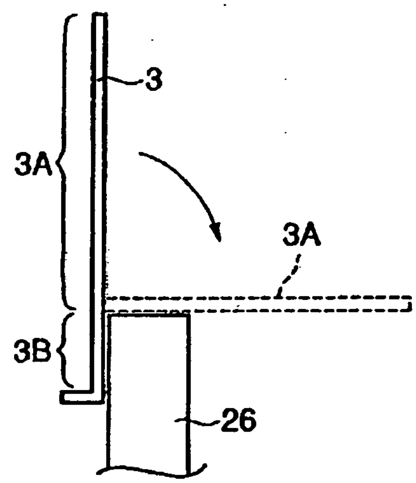


FIG. 5b

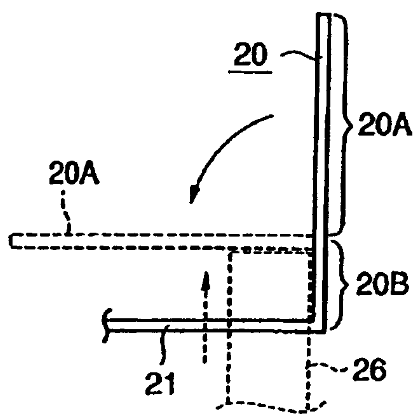


FIG. 6

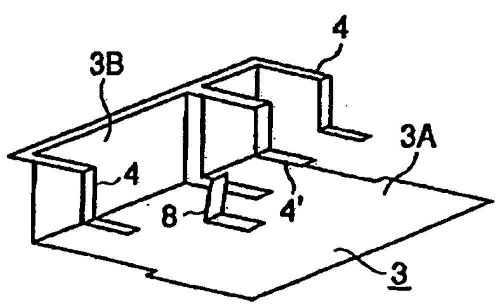


FIG. 7

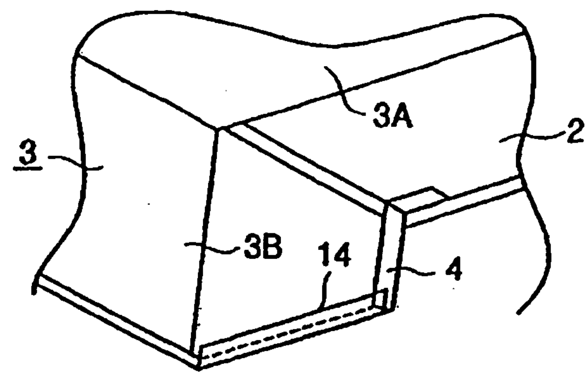


FIG. 8a

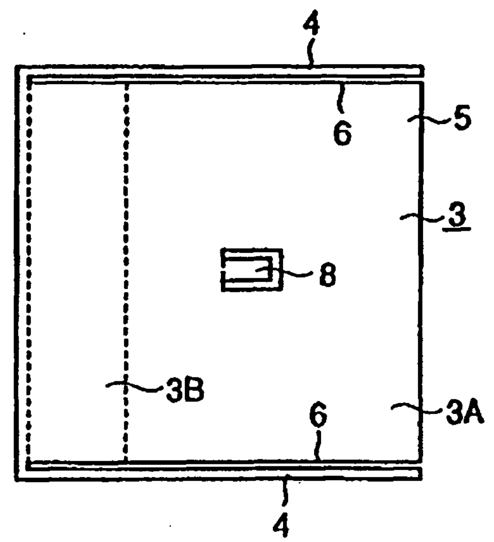


FIG. 8b

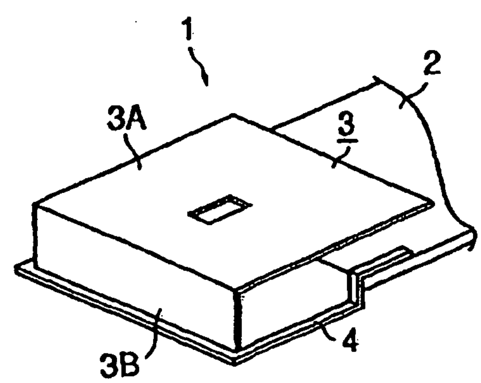


FIG. 9

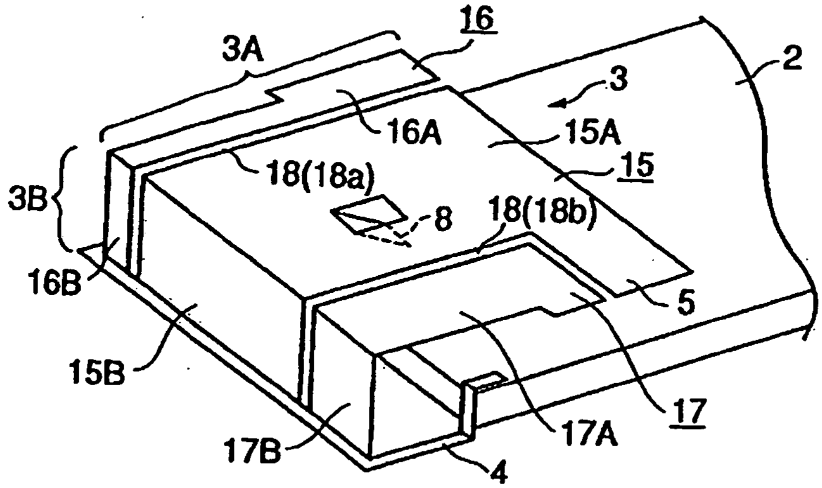


FIG. 10a

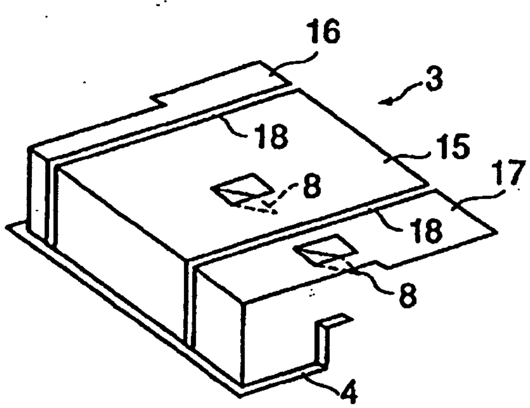


FIG. 10b

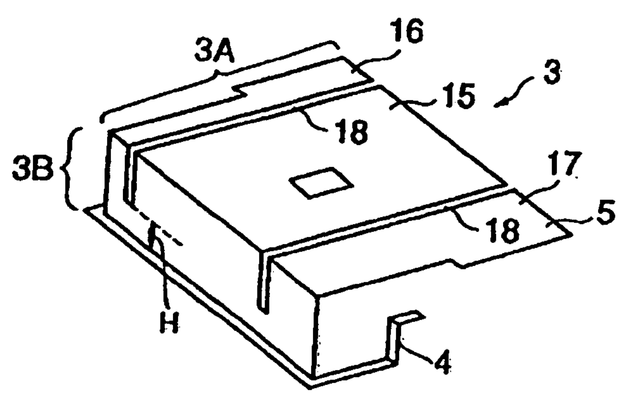


FIG. 11a

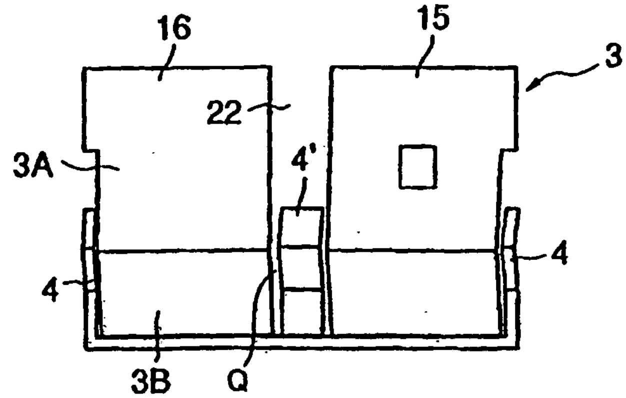


FIG. 11b

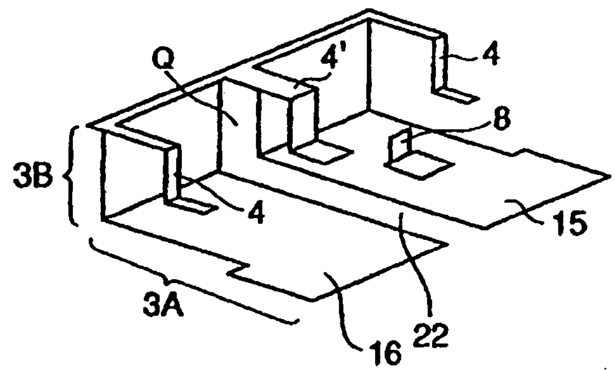


FIG. 12

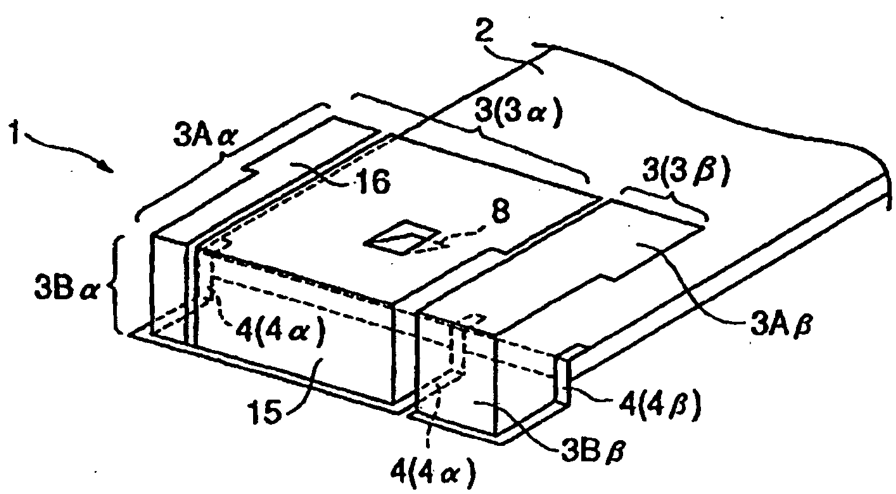


FIG. 13a

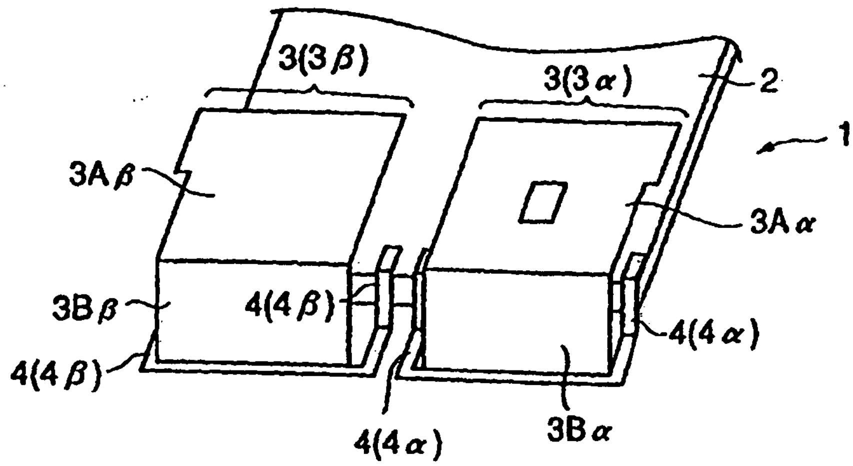


FIG. 13b

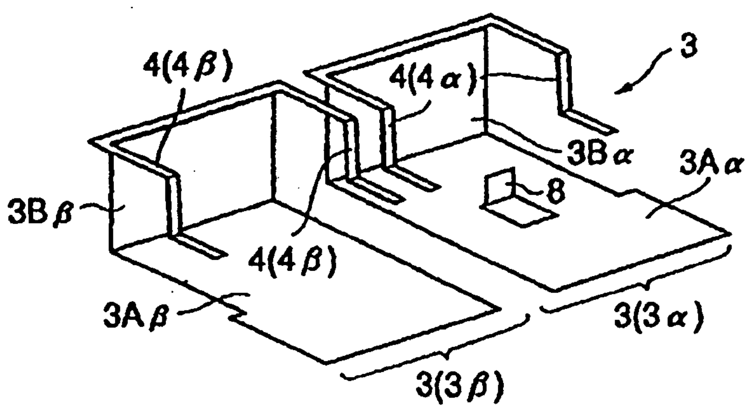


FIG. 14

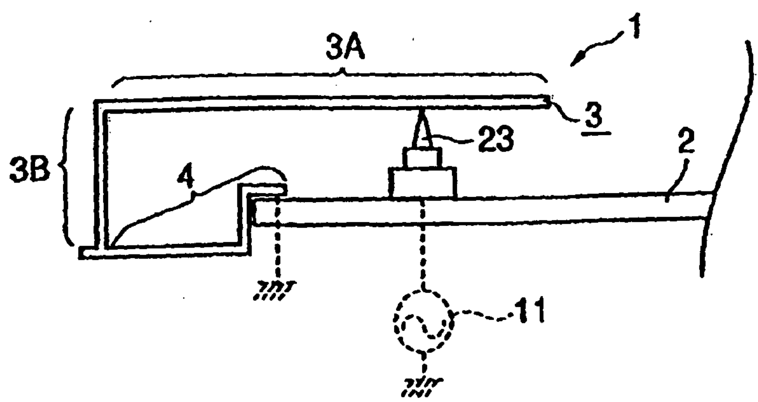


FIG. 15a

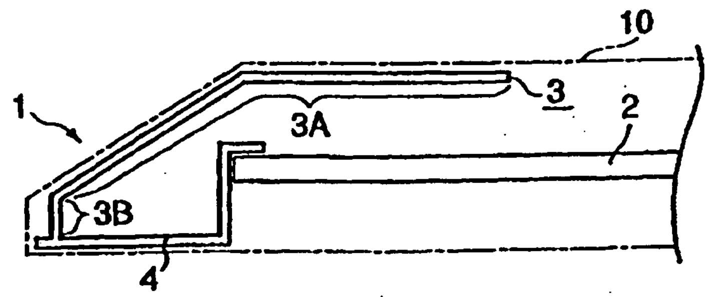


FIG. 15b

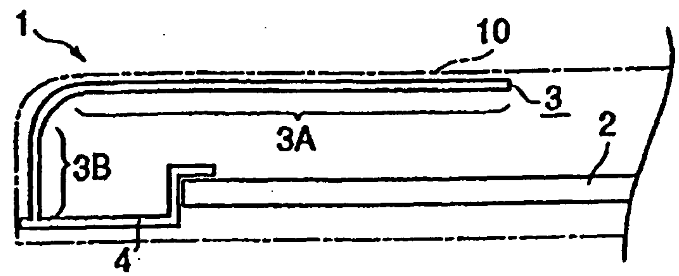


FIG. 16

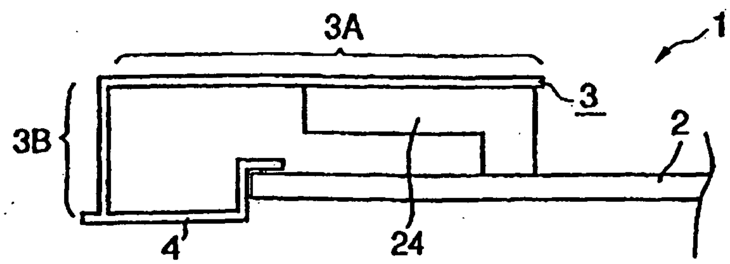


FIG. 17

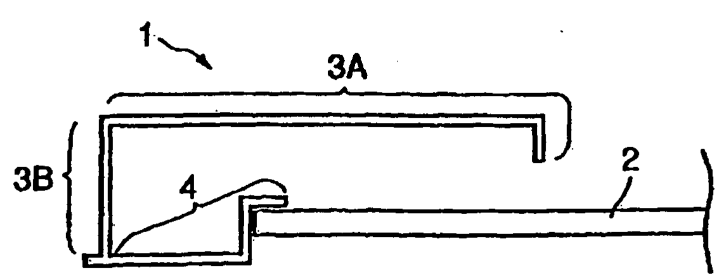


FIG. 18a

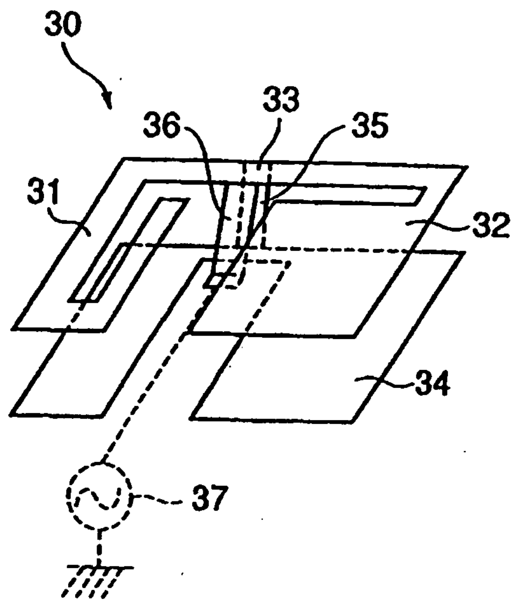
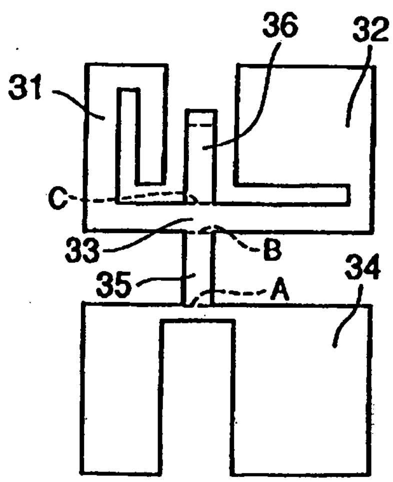


FIG. 18b



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2004/011995

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] H01Q13/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[7] H01Q13/08, H01Q1/24, H01Q5/01, H01Q9/40

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Toroku Jitsuyo Shinan Koho	1994-2004
Kokai Jitsuyo Shinan Koho	1971-2004	Jitsuyo Shinan Toroku Koho	1996-2004

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 7-193416 A (Seiko Epson Corp.), 28 July, 1995 (28.07.95), Par. Nos. [0051] to [0056]; Figs. 10 to 12 & EP 616384 A1 & US 5532705 A & US 5757326 A & US 5940041 A	1,2,4,14 3,5-13
Y	JP 1-245721 A (Matsushita Electric Works, Ltd.), 29 September, 1989 (29.09.89), Page 31, lower right column, line 19 to page 32, upper right column, line 19; Figs. 121 to 123 & US 4924237 A	3

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	WO 2001/24316 A1 (Murata Mfg. Co., Ltd.), 05 April, 2001 (05.04.01), Full text; Figs. 1 to 13 & US 6323811 B1 & EP 1162688 A1	5-9,12
Y	JP 10-200317 A (Nokia Mobile Phones Ltd.), 31 July, 1998 (31.07.98), Par. No. [0013]; Fig. 8 & EP 851531 A2 & US 6014113 A	11
Y	JP 2003-218628 A (NGK Insulators, Ltd.), 31 July, 2003 (31.07.03), Par. Nos. [0033], [0043]; Figs. 6, 14 & US 2003/107881 A1	13
A	JP 10-200327 A (Sharp Corp.), 31 July, 1998 (31.07.98), Par. Nos. [0040] to [0044]; Fig. 3 (Family: none)	1-14
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A	WO 2002/1670 A1 (ALL-GON AB.), 03 January, 2002 (03.01.02), Full text; Figs. 1 to 3 & SE 2387 A	1-14
A	JP 2001-251118 A (NEC Corp.), 14 September, 2001 (14.09.01), Par. Nos. [0021], [0022]; Fig. 5 & US 2001/21643 A1	1-14
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A	JP 8-111609 A (Murata Mfg. Co., Ltd.), 30 April, 1996 (30.04.96), Par. Nos. [0016], [0017] & EP 707355 A1	4

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